

## Physical Activity and Health

levels of occupational physical activity among Mexican Americans were associated with less NIDDM (Harris 1991). However, in contrast to findings from the First National Health and Nutrition Examination Survey (Chen and Lewenstein 1986), this association was not found for either occupational or leisure-time physical activity among blacks or whites.

Two case-control studies have found physical inactivity to be significantly associated with NIDDM (Kaye et al. 1991; Uusitupa et al. 1985). One was a population-based nested case-control study, in which women aged 55–69 years who had high levels of physical activity were found to be half as likely to develop NIDDM as were same-aged women with low levels of physical activity (age-adjusted OR = 0.5; 95% CI, 0.4–0.7) (Kaye et al. 1991). Moderately active women had an intermediate risk (OR = 0.7; 95% CI, 0.5–0.9).

Prospective cohort studies of college alumni, female registered nurses, and male physicians have demonstrated that physical activity protects against the development of NIDDM (Table 4-8). A study of

male university alumni (Helmrich et al. 1991) demonstrated that physical activity was inversely related to the incidence of NIDDM, a relationship that was particularly evident in men at high risk for developing diabetes (defined as those with a high BMI, a history of high blood pressure, or a parental history of diabetes). Each 500 kilocalories of additional leisure-time physical activity per week was associated with a 6 percent decrease in risk (adjusted for age, BMI, history of high blood pressure, and parental history of diabetes) of developing NIDDM. This study showed a more pronounced benefit from vigorous sports than from stair climbing or walking. In a study of female registered nurses aged 34–59 years, women who reported engaging in vigorous physical activity at least once a week had a 16 percent lower adjusted relative risk of self-reported NIDDM during the 8 years of follow-up than women who reported no vigorous physical activity (Manson et al. 1991). Similar findings were observed between physical activity and incidence of NIDDM in a 5-year prospective study of male physicians 40–84 years of age

**Table 4-8. Cohort studies of association of physical activity with non-insulin-dependent diabetes mellitus (NIDDM)**

Study	Population	Definition of physical activity	Definition of NIDDM
Helmrich et al. (1991)	Male college alumni	Leisure-time physical activity (walking, stair climbing, and sports)	Self-reported physician-diagnosed diabetes
Manson et al. (1991)	Female nurses	Single questions regarding number of times per week of vigorous activity	Self-reported diagnosed diabetes, confirmed by classic symptoms plus fasting plasma glucose $\geq 140$ mg/dl; two elevated plasma glucose levels on two different occasions; hypoglycemic medication use
Manson et al. (1992)	Male physicians	Single questions regarding number of times per week of vigorous activity	Self-reported physician-diagnosed diabetes

(Manson et al. 1992). Although the incidence of diabetes was self-reported in these cohorts, concerns about accuracy are somewhat mitigated by the fact that these were studies of health professionals and college-educated persons. In these three cohort studies, two found an inverse dose-response gradient of physical activity and the development of NIDDM (Helmrich et al. 1991; Manson et al. 1992).

In a feasibility study in Malmo, Sweden, physical activity was included as part of an intervention strategy to prevent diabetes among persons with impaired glucose tolerance (Eriksson and Lindgärde 1991). At the end of 5 years of follow-up, twice as many in the control group as in the intervention group had developed diabetes. The lack of random assignment of participants, however, limits the generalizability of this finding. A study conducted in Daqing, China, also included physical activity as an intervention to prevent diabetes among persons with impaired glucose tolerance (Pan, Li, Hu 1995). After 6 years of follow-up, 8.3 cases per 100 person-years occurred in the exercise intervention group and 15.7 cases per 100 person-years in the control group.

It has been recommended that an appropriate exercise program may be added to diet or drug therapy to improve blood glucose control and reduce certain cardiovascular risk factors among persons with diabetes (American Diabetes Association 1990). Diet and exercise have been found to be most effective for controlling NIDDM in persons who have mild disease and are not taking medications (Barnard, Jung, Inkeles 1994). However, excessive physical activity can sometimes cause persons with diabetes (particularly those who take insulin for blood glucose control) to experience detrimental effects, such as worsening of hyperglycemia and ketosis from poorly controlled diabetes, hypoglycemia (insulin-reaction) either during vigorous physical activity or—more commonly—several hours after prolonged physical activity, complications from proliferative retinopathy (e.g., detached retina), complications from superficial foot injuries, and a risk of myocardial infarction and sudden death, particularly among older people with NIDDM and advanced, but silent, coronary atherosclerosis. These risks can be minimized by a preexercise medical evaluation and by taking proper precautions (Leon 1989, 1992). To

Main findings	Dose response*	Adjustment for confounder and other comments
0.94 (95% CI, 0.90–0.98) or 6% decrease in NIDDM for each 500 kcal increment	Yes	Adjusted for age, BMI, hypertension history, parental history of diabetes
0.84 (95% CI, 0.75–0.94) for $\geq 1$ time per week vs. $< 1$ time per week vigorous activity	No	Adjusted for age, BMI, family history of diabetes, smoking, alcohol consumption, hypertension history, cholesterol history, family history of coronary heart disease
0.71 (95% CI, 0.54–0.94) for $\geq 1$ time per week vs. $< 1$ time per week vigorous activity	Yes	Adjusted for age, BMI, smoking, alcohol consumption, reported blood pressure, hypertension history, cholesterol history, parental history of myocardial infarction

Abbreviations: BMI = body mass index (wt [kg]/ht [m]<sup>2</sup>); CI = confidence interval.

\*A dose-response relationship requires more than 2 levels of comparison. In this column, "NA" means that there were only 2 levels of comparison; "No" means that there were more than 2 levels but no dose-response gradient was found; "Yes" means that there were more than 2 levels and a dose-response gradient was found.

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reduce risk of hypoglycemic episodes, persons with diabetes who take insulin or oral hypoglycemic drugs must closely monitor their blood glucose levels and make appropriate adjustments in insulin or oral hypoglycemic drug dosage, food intake, and timing of physical activity sessions.

### Biologic Plausibility

Numerous reviews of the short- and long-term effects of physical activity on carbohydrate metabolism and glucose tolerance describe the physiological basis for a relationship (Björntorp and Krotkiewski 1985; Koivisto, Yki-Järvinen, DeFronzo 1986; Lampman and Schteingart 1991; Horton 1991; Wallberg-Henriksson 1992; Leon 1992; Richter, Ruderman, Schneider 1981; Harris et al. 1987). During a single prolonged session of physical activity, contracting skeletal muscle appears to have a synergistic effect with insulin in enhancing glucose uptake into the cells. This effect appears to be related to both increased blood flow in the muscle and enhanced glucose transport into the muscle cell. This enhancement persists for 24 hours or more as glycogen levels in the muscle are being replenished. Such observations suggest that many of the effects of regular physical activity are due to the overlapping effects of individual physical activity sessions and are thus independent of long-term adaptations to exercise training or changes in body composition (Harris et al. 1987).

In general, studies of exercise training have suggested that physical activity helps prevent NIDDM by increasing sensitivity to insulin (Saltin et al. 1979; Lindgärde, Malmquist, Balke 1983; Krotkiewski 1983; Trovati et al. 1984; Schneider et al. 1984; Rönnemaa et al. 1986). These studies suggest that physical activity is more likely to improve abnormal glucose tolerance when the abnormality is primarily caused by insulin resistance than when it is caused by deficient amounts of circulating insulin (Holloszy et al. 1986). Thus, physical activity is likely to be most beneficial in preventing the progression of NIDDM during the earlier stages of the disease process, before insulin therapy is required. Evidence supporting this theory includes intervention programs that promote physical activity together with a low-fat diet high in complex carbohydrates (Barnard, Jung, Inkeles 1994) or programs that promote diet

alone (Nagulesparan et al. 1981). These studies have shown that diet and physical activity interventions are much less beneficial for persons with NIDDM who require insulin therapy than for those who do not yet take any medication or those who take only oral medications for blood glucose control.

Cross-sectional studies also show that, compared with their sedentary counterparts, endurance athletes and exercise-trained animals have greater insulin sensitivity, as evidenced by a lower plasma insulin concentration at a similar plasma glucose concentration, and increased <sup>125</sup>I-insulin binding to white blood cells and adipocytes (Koivisto et al. 1979). Insulin sensitivity and rate of glucose disposal are related to cardiorespiratory fitness even in older persons (Hollenbeck et al. 1984). Resistance or strength-training exercise has also been reported to have beneficial effects on glucose-insulin dynamics in some, but not all, studies involving persons who do not have diabetes (Goldberg 1989; Kokkinos et al. 1988). Much of the effect of physical activity appears to be due to the metabolic adaptation of skeletal muscle. However, exercise training may contribute to improved glucose disposal and glucose-insulin dynamics in both adipose tissue and the working skeletal muscles (Leon 1989, 1992; Gudat, Berger, Lefèbvre 1994; Horton 1991).

In addition, exercise training may reduce other risk factors for atherosclerosis (e.g., blood lipid abnormalities and elevated blood pressure levels), as discussed previously in this chapter, and thereby decrease the risk of macrovascular or atherosclerotic complications of diabetes (Leon 1991a).

Lastly, physical activity may prevent or delay the onset of NIDDM by reducing total body fat or specifically intra-abdominal fat, a known risk factor for insulin resistance. As discussed later in this chapter, physical activity is inversely associated with obesity and intra-abdominal fat distribution, and recent studies have demonstrated that physical training can reduce these body fat stores (Björntorp, Sjöström, Sullivan 1979; Brownell and Stunkard 1980; Després et al. 1988; Krotkiewski 1988).

### Conclusions

The epidemiologic literature strongly supports a protective effect of physical activity on the likelihood of developing NIDDM in the populations

studied. Several plausible biologic mechanisms exist to explain this effect. Physical activity may also reduce the risk of developing NIDDM in groups of people with impaired glucose tolerance, but this topic needs further study.

### Osteoarthritis

Osteoarthritis, the most common form of arthritis, is characterized by both degeneration of cartilage and new growth of bone around the joint. Because its prevalence increases with age, osteoarthritis is the leading cause of activity limitation among older persons. The etiology of osteoarthritis is unknown, and the risk factors and pathogenesis of osteoarthritis differ for each joint group.

Whether an active lifestyle offers protection against the development of osteoarthritis is not known, but studies have examined the risk of developing it in relation to specific athletic pursuits. Cross-sectional studies have associated competitive—as opposed to recreational—running at high levels and for long periods with the development of osteoarthritis seen on x-rays (Marti and Minder 1989; Kujala, Kaprio, Sarna 1994; Kujala et al. 1995). On the other hand, both cross-sectional and cohort studies have suggested that persons who engage in recreational running over long periods of time have no more risk of developing osteoarthritis of the knee or hip than sedentary persons (Lane 1995; Lane et al. 1986, 1993; Panush et al. 1995; Panush et al. 1986; Panush and Lane 1994). There is also currently no evidence that persons with normal joints increase their risk of osteoarthritis by walking.

Studies of competitive athletes suggest that some sports—specifically soccer, football, and weight lifting—are associated with developing osteoarthritis of the joints of the lower extremity (Kujala, Kaprio, Sarna 1994; Kujala et al. 1995; Rall, McElroy, Keats 1964; Vincelette, Laurin, Lévesque 1972; Lindberg, Roos, Gärdsell 1993). Other competitive sports activities in which specific joints are used excessively have also been associated with the development of osteoarthritis. For example, baseball pitchers are reported to have an increased prevalence of osteoarthritis in the elbow and shoulder joint (Adams 1965; Bennett 1941). These studies are limited because they

involve small sample sizes. Further confounding these studies is the high incidence of fractures, ligamentous and cartilage injuries, and other injuries to joints that occur with greater-than-average frequency among competitive participants in these sports. Because joint injury is a strong risk factor for the development of osteoarthritis, it may not be the physical activity but rather the associated injuries that cause osteoarthritis in these competitive athletes. In a study by Roos and colleagues (1994), soccer players who had not suffered knee injuries had no greater prevalence of osteoarthritis than did sedentary controls. Regular noncompetitive physical activity of the amount and intensity recommended for improving health thus does not appear harmful to joints that have no existing injury.

### Physical Activity in Persons with Arthritis

Given the high prevalence of osteoarthritis among older people, it is important to determine whether persons with arthritis can safely exercise and be physically active. Experimental work with animals shows that use of injured joints inhibits tissue repair (Buckwalter 1995). More specifically, several studies have indicated that running accelerates joint damage in animal models where osteoarthritis has been experimentally induced (Armstrong et al. 1993).

In contrast, several short-term studies of human subjects have indicated that regular moderate-exercise programs, whether including aerobic or resistance training, relieve symptoms and improve function among people with both osteoarthritis and rheumatoid arthritis (Ettinger and Afbale 1994; Allegrante et al. 1993; Fisher et al. 1991; Fisher et al. 1994; Fisher and Pendergast 1994; Puett and Griffin 1994). For example, it has been shown that after regular physical activity, persons with arthritis have a significant reduction in joint swelling (Minor et al. 1988). In other studies of persons with osteoarthritis, increased levels of physical activity were associated with improved psychosocial status, functional status, and physical fitness (Minor 1991; Minor and Brown 1993). Furthermore, regular physical activity of moderate intensity has been found to raise the pain threshold, improve energy level, and improve self-efficacy among persons with osteoarthritis (Minor et al. 1989; Chow et al. 1986; Holman, Mazonson, Lorig 1989).

### Biologic Plausibility

The biologic effects of physical activity on the health and function of joints have not been extensively investigated, but some level of physical activity is necessary to preserve joint function. Because hyaline cartilage has no blood vessels or nerves, mature cartilage cells (chondrocytes) receive nourishment only from the diffusion of substances through the cartilage matrix from joint fluid. Physical activity enhances this process. In the laboratory, putting pressure on cartilage deforms the tissue, creating pressure gradients that cause fluid to flow and alter osmotic pressures within the cartilage matrix (Hall, Urban, Gohl 1991). The effect of such loading on the metabolism of chondrocytes is not well described, but when loading is performed within the physiologic range, chondrocytes increase proteoglycan synthesis (Grodzinsky 1993). In contrast, high-intensity loading and repetitive high-impact loads disrupt the cartilage matrix and inhibit proteoglycan synthesis (Lammi 1993).

The role of normal loading is confirmed by the effect of inactivity on articular cartilage. Immobility leads to decreased cartilage proteoglycan synthesis, increased water content, and decreased cartilage stiffness and thickness. Disuse may make the cartilage more vulnerable to injury, and prolonged disuse causes loss of normal joint function as the joint cavity is obliterated by fibrous tissue.

Studies of running on joint function in dogs with normal joints have confirmed that running does affect the proteoglycan and water content of cartilage and does not lead to degeneration of articular surfaces or to degenerative joint disease (Arokoski et al. 1993). In contrast, in dogs with injured joints, running has been shown to cause arthritis (Buckwalter 1995).

### Conclusions

Physical activity is essential for maintaining the health of joints and appears to be beneficial for control of symptoms among people with osteoarthritis. Although there is no evidence that physical activity itself causes osteoarthritis, injuries sustained during competitive sports have been shown to increase the risk of developing osteoarthritis.

### Osteoporosis

Osteoporosis is characterized by decreased bone mass and structural deterioration of bone tissue, leading to bone fragility and increased susceptibility to fractures. Because bone mass and strength progressively decline with advancing age, this disease primarily affects older persons (Cummings et al. 1985). Osteoporosis is more common among women than among men, for at least three reasons: women have lower peak bone mass than men, women lose bone mass at an accelerated rate after menopause when estrogen levels decline, and women have a longer life span than men.

The most common potential fracture sites are vertebrae of the chest and lower back, the distal radius (or wrist), the hips, and the proximal humerus (NIH 1984). Vertebral fractures can occur spontaneously or with minimal trauma (e.g., bending forward or coughing); once deformed, the vertebrae never return to their normal shape. These fractures may be asymptomatic and discovered only incidentally on a chest or spine x-ray. Accumulation of such vertebral fractures causes a bent-over or hunchbacked posture that is generally associated with chronic back pain and often with gastrointestinal and abdominal problems related to a lowering of the rib cage.

In the United States, fractures of the hip account for 250,000 of the 1.5 million fractures that are attributed each year to osteoporosis. Hip fractures are associated with more deaths (a 15–20 percent 1-year mortality rate), permanent disability, and medical and institutional care costs than all other osteoporotic fractures combined (Cummings et al. 1985; Rankin 1993). By age 90, about one-third of women and about one-sixth of men will have sustained a hip fracture.

In both men and women, the development of osteoporosis may be related to three factors: a deficient level of peak bone mass at physical maturity, failure to maintain this peak bone mass during the third and fourth decades of life, and the bone loss that begins during the fourth or fifth decade of life. Physical activity may positively affect all three of these factors.

Physical activity may play a substantial role in the development of bone mass during childhood and adolescence and in the maintenance of skeletal mass

as a young adult. This inference is partly based on findings that athletic young adults have a higher density of bone mineral than sedentary young adults (Kirchner, Lewis, O'Connor 1996; Grimston, Willows, Hanley 1993; Conroy et al. 1993; Nichols et al. 1994; Rubin et al. 1993), on reports that athletes have a differential density of bones according to the sport they train for (Robinson et al. 1995; Heinonen et al. 1995), and on evidence that increase in bone mass in university students is related to higher levels of physical activity (Recker et al. 1992).

Beyond this hypothesized function in youth, physical activity plays a well-established role throughout the life span in maintaining the normal structure and functional strength of bone. Prolonged bed rest or immobility causes rapid and marked reduction in bone mineral density (Krølner et al. 1983; Chesnut 1993; Donaldson et al. 1970). Of particular public health interest is the degree to which physical activity can prevent or slow the bone loss that begins occurring in women as a normal process after menopause. Cross-sectional studies of postmenopausal women have shown that bone mineral density is correlated with muscle strength (Sinaki et al. 1986; Sinaki and Offord 1988), physical activity (Sinaki and Offord 1988; Shimegi et al. 1994; Jacobson et al. 1984; Talmage et al. 1986), and cardiorespiratory fitness (Pocock et al. 1986; Chow et al. 1986). Longitudinal studies of postmenopausal women have attributed increases in both cardiorespiratory fitness and bone mass to physical activity (Chow et al. 1987; Dalsky et al. 1988). There is some evidence that through physical activity, osteoporotic women can minimize bone loss or facilitate some gain in bone mineral content (Krølner et al. 1983; Kohrt et al. 1995). However, other studies have failed to show such benefits (Nelson et al. 1991; Sandler et al. 1989; Cavanaugh and Cann 1988). The intensity of the physical activity and the degree to which it stresses the bones may be crucial factors in determining whether bone mass is maintained. Thus it is likely that resistance exercise may have more pronounced effects than endurance exercise, although this has not yet been unequivocally established.

Several investigators have found that the positive effect of physical activity on the bones of both premenopausal and postmenopausal women depends

on the presence of estrogen. In postmenopausal women, greater gain in bone density accrues when physical activity and estrogen replacement therapy occur simultaneously (Prince et al. 1991; Kohrt et al. 1995). In young, premenopausal women, however, excessive amounts of vigorous training may lead to a low estrogen level and secondary amenorrhea, with subsequent decreased bone mass and increased risk of stress fractures (Marcus et al. 1985; Drinkwater et al. 1984; Allen 1994).

The exercise-associated changes in bone mineral density observed over time among both premenopausal and postmenopausal women are much less pronounced than those differences observed cross-sectionally between active and sedentary persons (Drinkwater 1993). Cross-sectional studies demonstrate differences of 10–15 percent in bone mineral density at various sites (Aloia et al. 1988; Lane et al. 1986; Michel, Bloch, Fries 1989; Recker et al. 1992), whereas intervention studies show smaller gains of 1–5 percent (Krølner et al. 1983; Dalsky et al. 1988; Nelson et al. 1991; Pruitt et al. 1992; Drinkwater 1993). These differences may be due to differences in comparison groups, to follow-up duration insufficient to show large changes in bone mineral density, or to measurement at different skeletal sites. Still to be conducted are well-designed randomized clinical trials that are of sufficient size and duration to determine definitively the longitudinal effects of physical activity change or the differential effects of resistance and endurance activity on bone mineral density.

### Biologic Plausibility

Bone is a dynamic tissue that is constantly remodeling its structure by resorption and formation. Physical activity, through its load-bearing effect on the skeleton, is likely the single most important influence on bone density and architecture (Lanyon 1996). Bone cells respond to mechanical loading by improving the balance between bone formation and bone resorption, which in turn builds greater bone mass (Lanyon 1987, 1993). The higher the load, the greater the bone mass; conversely, when the skeleton is unloaded (as with inactivity), bone mass declines. Glucose-6-phosphate, prostaglandins, and nitric oxide play a role in mediating the mechanical

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loading effect on bone (Pitsillides et al. 1995; Turner et al. 1995; Tang et al. 1995). Because it is muscle that exerts the largest forces on bone during physical activity, the role of muscle mass and strength in maintaining skeletal integrity should be explored more fully.

Nonmechanical factors, such as age, hormonal milieu, nutritional intake, and medications, are increasingly being recognized as important determinants of the bone's response to mechanical loading (Lanyon 1996). The relative contributions of each of these factors are currently under study and are not yet clearly delineated. Animal studies confirm a difference in bone response to mechanical loading with age and by estrogen status (Turner, Takano, Owan 1995). The potential clinical relevance of this research is to better define the optimal amount and type of exercise for maintaining or increasing bone mass, particularly with aging or in the absence of estrogen replacement therapy after menopause.

### Physical Activity and the Prevention of Fractures and Falling

Studies of physical activity in relation to hip fracture in women have generally found a lower risk of hip fracture among those who were more active. Three cohort studies have reported such a protective effect. One showed a statistically significant protective effect among those reporting the most recreational activity at baseline (Farmer et al. 1989), one showed inverse but not statistically significant associations for both work and leisure-time physical activity (Meyer, Tverdal, Falch 1993), and one showed a significant protective effect of walking for exercise (Cummings et al. 1995). Case-control studies have been more equivocal. One such study found a significant protective effect for two levels of past activity, but for recent activity only moderate amounts of activity showed a significant protective effect (Jaglal, Kreiger, Darlington 1993). Another case-control study showed inconsistent effects across a variety of physical activity classifications (Cumming and Klineberg 1994).

Nonskeletal factors that increase the risk of fractures due to falls include limitations in activities of daily living (e.g., dressing and feeding oneself); compromised gait, balance, reaction time,

and muscle strength; impaired vision; medication use; and environmental hazards (Dunn et al. 1992; Gilligan, Checovich, Smith 1993; Tinetti, Speechley, Ginter 1988; Cummings et al. 1995). Various exercises may help prevent falls by improving muscle strength, functional capacity, gait, balance, and reaction time. Tinetti and colleagues (1994) showed a significant decrease in falls in the elderly concomitant with an improvement in balance and gait achieved through exercise. Province and colleagues (1995) demonstrated a protective effect against falls through general exercise and exercises designed to improve balance. Moreover, Fiatarone and colleagues (1994) have shown that even frail elderly persons who have multiple chronic diseases benefit substantially from resistance training. This well-controlled randomized trial demonstrated the importance of strength training in improving stair-climbing power, gait, and other measures of physical function. Moderate exercise-training techniques, such as tai chi chuan, have also been shown to decrease falling and to improve function in older adults by increasing or maintaining aerobic power, strength, and balance (Lai et al. 1995; Wolf et al. 1996; Wolfson et al. 1996).

### Conclusions

Physical activity appears to build greater bone mass in childhood and early adolescence and to help maintain peak bone mass in adulthood. Among women after menopause, physical activity may protect against the rapid decline in bone mass, but findings are inconsistent in this regard, and it is unclear whether muscle-strengthening (resistance) activity may be more effective than endurance activity for this purpose. Estrogen replacement therapy has been shown conclusively to decrease bone loss after menopause, and there is evidence that this effect is enhanced with physical activity. However, it is not clear whether physical activity alone, in the absence of estrogen replacement therapy, can prevent bone loss.

Physical activity, including muscle-strengthening (resistance) exercise, appears to be protective against falling and fractures among the elderly, probably by increasing muscle strength and balance.

### Obesity

Obesity, a major public health problem in the United States, plays a central role in the development of diabetes mellitus (West 1978) and confers an increased risk for CHD, high blood pressure, osteoarthritis, dyslipoproteinemia, various cancers, and all-cause mortality (Hubert et al. 1983; Bray 1985; Albanes 1987; Lee et al. 1993; Manson et al. 1995). The progressive weight gain often observed between the third and sixth decades of life may be partly explained by age-related changes: although energy intake tends to decline after the second decade of life, this decrease is insufficient to offset the greater decline in the amount of energy that most people expend throughout their adult years (Bray 1983; Federation of American Societies for Experimental Biology 1995). In addition to these age trends, population surveys indicate that the age-adjusted prevalence of overweight among adults in the United States has increased from about 25 percent in the 1970s to 33 percent in 1988–1991 (Kuczmarski et al. 1994). The increase is evident for all race and sex groups. This phenomenon is believed to be due to high rates of inactivity combined with easy access to energy-dense food (Blackburn and Prineas 1983).

Obesity, defined as an excess of adipose tissue, is difficult to measure in population-based studies. Most investigations have therefore either used a relative weight index, such as percent desirable weight (Metropolitan Life Insurance Company 1959), or have used BMI (defined by a ratio of weight to height) as a surrogate measure. Quetelet's index ( $\text{weight [kg]} / \text{height [m]}^2$ ) has been the most frequently used BMI. Although these weight-height indices are strongly correlated with more direct measures of adiposity, such as underwater weighing, they have limitations: fatty tissue cannot be distinguished from muscle mass or edema, and associations between weight-height indices and adiposity may be nonlinear or may differ by age or ethnic group (Harrison et al. 1985; Garn, Leonard, Hawthorne 1986; Lillioja and Bogardus 1988). Despite these limitations, BMI has shown a monotonic association with mortality in several recent cohort studies (Lee et al. 1993; Manson et al. 1995; Willett et al. 1995).

Using nationally representative data, the CDC has defined overweight as a Quetelet's index at or above the 85th percentile for 20- to 29-year-olds

( $\geq 27.3 \text{ kg/m}^2$  for women,  $\geq 27.8 \text{ kg/m}^2$  for men), corresponding to 120–125 percent of desirable weight (NIH 1985; Kuczmarski 1992; Kuczmarski et al. 1994). The 95th percentile of Quetelet's index ( $32.3 \text{ kg/m}^2$  for women,  $31.1 \text{ kg/m}^2$  for men), equivalent to a relative weight of approximately 145 percent, has been used to classify persons as severely overweight. Between 1976 and 1991, the mean weight of U.S. adults increased by 3.6 kg (almost 8 pounds), and 58 million American adults (33 percent) are now considered to be overweight (Kuczmarski et al. 1994).

Because substantial weight loss in adults is difficult to achieve and maintain (Dyer 1994), childhood obesity and its prevention have received increased attention. Overweight children are likely to remain overweight as adolescents and adults (Johnston 1985) and are subsequently at increased risk for high blood pressure, diabetes, CHD, and all-cause mortality (Abraham, Collins, Nordsieck 1971; Nieto, Szklo, Comstock 1992; Must et al. 1992). Moreover, paralleling the trend seen among adults, the prevalence of overweight among U.S. children and adolescents has increased substantially over the past decade (Shear et al. 1988; Troiano et al. 1995).

### Physical Activity and Obesity

It is commonly believed that physically active people are less likely to gain weight over the course of their lives and are thus more likely to have a lower prevalence of obesity than inactive people; accordingly, it is also commonly believed that low levels of physical activity are a cause of obesity. Few data, however, exist to evaluate the truth of these suppositions.

Several cross-sectional studies report lower weight, BMI, or skinfold measures among people with higher levels of self-reported physical activity or fitness (DiPietro 1995; Ching et al. 1996; Williamson et al. 1993; French et al. 1994; Folsom et al. 1985; Dannenberg et al. 1989; Slattery et al. 1992; Gibbons et al. 1983; Voorrips et al. 1992). Prospective studies have shown less consistent results. French and colleagues (1994) reported an inverse association between leisure-time physical activity (either walking or engaging in high-intensity activity) and later weight gain, and Ching and colleagues (1996) found that physical activity was inversely related to the risk of becoming overweight. Klesges and colleagues (1992) reported that weight gain was



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inversely associated with leisure-time physical activity among women but not among men. Williamson and colleagues (1993), however, found no association between physical activity and subsequent weight change. Williamson and colleagues (1993) and Voorrips and colleagues (1992) proposed that decreases in physical activity may be both a cause and a consequence of weight gain over a lifetime and that multiple measurements over time may be necessary to characterize the interrelationship. One cohort study that assessed changes in physical activity reported that among women, decreased physical activity performed as work was related to weight gain; no associations were found among men (Klesges et al. 1992).

The relationship between physical activity and obesity in children is still under investigation. Some studies comparing obese and nonobese children have shown higher physical activity levels in nonobese children (Johnson, Burke, Mayer 1956; Bullen, Reed, Mayer 1964); others have shown little or no relationship (Stefanik, Heald, Mayer 1959; Bradfield, Paulos, Grossman 1971). Somewhat inconsistent results have also been seen in cross-sectional studies, with several finding lower BMIs or skinfold measures among children with higher levels of physical activity or fitness (Wolf et al. 1993; Obarzanek et al. 1994; Strazzullo et al. 1988; Tell and Vellar 1988) and some smaller studies finding no association (Sallis et al. 1988; LaPorte et al. 1982). More recently, two longitudinal studies have reported inverse relationships between physical activity and triceps skinfold measures (Moore et al. 1995) and BMI (Klesges et al. 1995) in young children. A third longitudinal study (Ku et al. 1981) found a significant negative association between physical activity and percentage of body fat in boys but not in girls. Additional longitudinal studies of children, including measurement of changes in physical activity, will help clarify whether physical activity prevents the development of obesity.

Over the past two decades, several comprehensive review articles (Oscai 1973; Stefanick 1993; Thompson, Jarvie, et al. 1982; Wilmore 1983), as well as two meta-analyses (Ballor and Keesey 1991; Epstein and Wing 1980), have examined the impact of exercise training on body weight and obesity. These reviews conclude that 1) physical activity

generally affects body composition and weight favorably by promoting fat loss while preserving or increasing lean mass; 2) the rate of weight loss is positively related, in a dose-response manner, to the frequency and duration of the physical activity session, as well as to the duration (e.g., months, years) of the physical activity program; and 3) although the rate of weight loss resulting from increased physical activity without caloric restriction is relatively slow, the combination of increased physical activity and dieting appears to be more effective for long-term weight regulation than is dieting alone (Brownell and Stunkard 1980; Kayman, Bruvold, Stern 1990).

Independent of its effect on body weight and total adiposity, physical activity may favorably affect fat distribution. Several large cross-sectional studies in Europe (Seidell et al. 1991), Canada (Tremblay et al. 1990), and the United States (Kaye et al. 1990; Slattery et al. 1992; Troisi et al. 1991; Wing et al. 1991) report an inverse association between energy expenditure from physical activity and several indicators of central body fat distribution, such as the waist-to-hip ratio or the waist-to-thigh-circumference ratio.

### Biologic Plausibility

Increase in fat mass and the development of obesity occur when energy intake exceeds total daily energy expenditure for a prolonged period (Bray 1983; Leibel, Rosenbaum, Hirsch 1995). Total energy expenditure represents the sum of 1) resting energy expenditure for maintaining basic body functions (approximately 60 percent of total energy requirements); 2) the thermic effect of eating for digestion, absorption, transport, and deposition of nutrients (about 10 percent); and 3) nonresting energy expenditure, primarily in the form of physical activity (about 30 percent) (Leibel, Rosenbaum, Hirsch 1995). This third component, nonresting energy expenditure, is the most variable. Energy balance tilts to weight gain when disproportionately more energy is taken in; theoretically, about one pound (or 0.45 kg) of fat energy is stored for each 3,500 kilocalories of excess energy intake. By increasing nonresting energy expenditure, regular physical activity contributes to weight maintenance and weight reduction. Evidence supports the metabolic and

physiological benefits of incorporating physical activity into programs that prevent or manage obesity (Pi-Sunyer 1988; Leon 1989; Bouchard, Després, Tremblay 1993; DiPietro 1995; Ewbank, Darga, Lucas 1995).

Controversy exists over whether physical activity following a meal increases the thermic effect of food ingestion and whether physical activity before a meal reduces appetite. The evidence suggests that physical activity programs do not necessarily produce a compensatory increase in food intake in obese individuals (Woo, Garrow, Pi-Sunyer 1982a, 1982b). Moreover, daily physical activity may further assist in weight loss by partially reducing the decline in resting energy expenditure that occurs during dieting and associated weight loss (Lennon et al. 1985). This effect is plausible because endurance exercise and strength training may help preserve, to some degree, metabolically active, lean body mass, whereas caloric restriction does not (Hill, Drougas, Peters 1994; Ballor and Keesy 1991).

Because abdominal fat is more responsive than gluteal or lower-body fat to epinephrine stimulation (Wahrenberg, Bolinder, Arner 1991), physical activity may result in a more beneficial redistribution of body fat in both sexes (Bouchard, Després, Tremblay 1993). Further investigation, however, is needed to clarify the associations between gonadal hormone levels, baseline regional fat distribution, and exercise-related changes in weight and body fat distribution.

### Conclusions

Physical activity is important for weight control. By using energy and maintaining muscle mass, physical activity is a useful and effective adjunct to dietary management for avoiding weight gain or losing weight. Physical activity appears to favorably affect distribution of body fat.

### Mental Health

Mental disorders pose a significant public health burden in the United States. Some disorders, such as depression, are associated with suicide, which is currently the ninth leading cause of death among Americans (NCHS 1996). A major cause of hospitalization and disability, mental disorders cost \$148

billion per year, about half of which is due to severe mental illness (National Advisory Mental Health Council 1993).

The annual prevalence of mental disorders in the United States population is high. Nearly three out of 10 persons 15–54 years of age who live in households report having had a mental disorder during the previous year (Regier et al. 1993; Kessler et al. 1994). The most frequently reported disorders are affective (mood) and anxiety disorders. More than one out of 10 adults suffers from a depressive disorder in any given year; between 13 and 17 percent suffer from an anxiety disorder. Women report a higher prevalence of affective and anxiety disorders than do men. Most people with mental disorders do not obtain any professional treatment; only one in five people with a disorder during the previous year has received help from a health service provider.

Mental disorders, mental illnesses, mental health, and psychological well-being relate to such factors as mood or affect, personality, cognition, and perception. Psychological constructs about these factors are interrelated with a person's physical health status and quality of life. In studies of the effects of physical activity on mental health, the most frequently studied outcomes include mood (anxiety, depression, negative affect, and to a lesser extent, positive affect), self-esteem, self-efficacy, and cognitive functioning. The general hypothesis is that people who are physically active or have higher levels of cardiorespiratory fitness have enhanced mood (less negative and greater positive affect), higher self-esteem, greater confidence in their ability to perform tasks requiring physical activity (i.e., greater self-efficacy), and better cognitive functioning than sedentary persons or those who are less physically fit. One National Institutes of Mental Health workshop (Morgan and Goldston 1987) and numerous recent reviews have been devoted to this literature (Brown 1990; LaFontaine et al. 1992; Landers and Petruzzello 1994; Martinsen and Stephens 1994; McAuley 1994; McDonald and Hodgdon 1991; Morgan 1994; North, McCullagh, Tran 1990; Plante and Rodin 1990; Raglin 1990; Sime 1990). The effects of physical activity on most mental disorders—including sleep and eating disorders, schizophrenia, dementia, personality disorders, and substance-related disorders—are not as well studied

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(Dishman 1986; Taylor, Sallis, Needle 1985; Martinsen and Stephens 1994).

This section focuses primarily on the association of physical activity with anxiety and depression. Evidence related to other psychological factors, such as positive affect, self-esteem, self-efficacy, and cognitive functioning, is discussed later in this chapter in the "Health-Related Quality of Life" section.

### Physical Activity and Mental Health

Epidemiologic research among men and women suggests that physical activity may be associated with reduced symptoms of depression (Ross and Hayes 1988; Stephens 1988; Stephens and Craig 1990; Farmer et al. 1988; Camacho et al. 1991), clinical depression (Weyerer 1992), symptoms of anxiety (Ross and Hayes 1988; Stephens 1988), and improvements in positive affect (Stephens 1988; Stephens and Craig 1990) and general well-being (Stephens 1988). In general, persons who are inactive are twice as likely to have symptoms of depression than are more active persons.

Most epidemiologic and intervention studies on the relationship of physical activity and mental health have used self-report questionnaires to assess symptoms of anxiety and depression among persons from the general population, although some studies have focused on patients diagnosed by clinicians. These questionnaires are useful for identifying persons experiencing mental distress (i.e., symptoms of anxiety or depression), but such identifications do not necessarily correspond to diagnoses of anxiety or depression by clinicians using standard interview criteria (Fechner-Bates, Coyne, Schwenk 1994).

The literature suggests that physical activity helps improve the mental health of both clinical and nonclinical populations. Physical activity interventions have benefited persons from the general population who report mood disturbance (Simons and Birkimer 1988; Wilfley and Kuncze 1986), including symptoms of anxiety (Steptoe et al. 1989) and depression (Morgan et al. 1970), as well as patients who have been diagnosed with nonbipolar, nonpsychotic depression (Doyle et al. 1987; Klein et al. 1985; Martinsen, Medhus, Sandvik 1985). These findings are supported by a limited number of intervention studies conducted in community and laboratory settings (Brown 1990; Landers and Petruzzello

1994; Martinsen and Stephens 1994; McAuley 1994; Morgan 1994; Plante and Rodin 1990; Sime 1990). Intervention studies have primarily evaluated the effects of aerobic physical activities, such as brisk walking and running, on mental health; how other forms of physical activity, such as strength training, affect mental health requires further study.

The psychological benefits of regular physical activity for persons who have relatively good physical and mental health are less clear. Some intervention studies have found that physical activity provides mental health benefits to persons recruited from the community who are without serious psychological problems. These benefits included increases in general well-being (Cramer, Nieman, Lee 1991) and reductions in tension, confusion (Moses et al. 1989), and perceived stress and anxiety (King, Taylor, Haskell 1993). Other researchers have found that few (Brown et al. 1995; Blumenthal et al. 1989; King, Taylor, Haskell 1989) or no mental health benefits (Hughes, Casal, Leon 1986; Lennox, Bedell, Stone 1990) occurred among people without mental disorders who participated in physical activity interventions.

Most of these studies involved relatively small sample sizes. Furthermore, the participants had little opportunity to show improvement on objective and standardized mental health measures, since their baseline scores were already in the normal range or lower on measures of negative affect and were in the normal range or higher for positive affect. Even when no change was observed on objective measures, in some of these studies, participants reported feeling a subjective sensation of improved physical, psychological, or social well-being after participating in regular physical activity (Blumenthal et al. 1989; King, Taylor, Haskell 1993).

Psychological assessments that have been used in physical activity research have included state and trait measures. State measures, which reflect how a person feels "right now," are particularly useful in assessing changes in mood that occur before and after an intervention, such as a single episode of physical activity. Trait measures, which evaluate how a person "generally" feels, focus on personality characteristics that tend to be stable or sustained across the life span. Although physical activity training programs can result in sustained psychological

benefits, many people after a single session of physical activity report improvements in transient moods, such as reduced anxiety (Morgan 1979a; Roth 1989), and have temporary reductions in muscular tension (DeVries 1981; DeVries and Adams 1972). The reduction in anxiety may persist for 2 to 6 hours following a session of physical activity (Landers and Petruzzello 1994; Raglin and Morgan 1987). Regular daily physical activity is required to experience this calming effect on an ongoing basis. Some researchers have thus proposed that the episodic mental health benefits associated with physical activity may act as an important preventive measure that could lead to the maintenance of mental health over time (Morgan 1981; Morgan et al. 1980; Raglin 1990).

A number of epidemiologic studies of noninstitutionalized populations have evaluated the associations between self-reported levels of physical activity and mental health. These studies typically assessed retrospective self-reports of leisure-time physical activity during the previous several weeks or more. How these assessments relate to changes in cardiorespiratory fitness is unknown. The available evidence indicates, however, that increases in cardiorespiratory fitness are not necessary for psychological benefits to occur (Brown and Wang 1992; King, Taylor, Haskell 1989; Landers and Petruzzello 1994; Martinsen and Stephens 1994).

Cross-sectional epidemiologic or community population studies support an association between physical activity and psychological well-being in the general population. For example, in one cross-sectional study using data generated from a state telephone survey, researchers determined that adults ( $n = 401$ ) who spent more time participating in regular exercise, sports, or other physical activities had fewer symptoms of depression and anxiety than persons reporting no physical activity or low levels of participation (Ross and Hayes 1988). These associations were similar for men and women and for older and younger adults. The cause-and-effect relationship, however, cannot be determined because physical activity and mood were measured at the same time.

In another cross-sectional study (Stephens 1988), secondary analyses of two Canadian surveys ( $n = 23,791$  and  $22,250$  young people and adults) and two U.S. surveys ( $n = 3,025$  and  $6,913$  adults) conducted

between 1971 and 1981 associated physical activity with fewer symptoms of anxiety and depression and with higher positive mood and general well-being. These associations were observed in all four surveys, even though they used different measures of physical activity and mental health, and were strongest among women and among persons aged 40 years or older. However, one of the Canadian surveys found that women manifested higher positive affect when their energy expenditure scores were based on recreational activities only, rather than on a combination of recreational and household activities. Hence, mental health outcomes may depend on the type of physical activities being performed and perhaps on the setting in which they occur. This finding is important in that investigators have typically evaluated the mental health effects of recreational aerobic activities, such as running, rather than occupational and household activities.

A subsequent nationwide Canadian survey (Stephens and Craig 1990) of approximately 4,000 respondents aged 10 years and older found that persons who reported higher levels of total daily leisure-time energy expenditure had a more positive mood than persons reporting lower levels of expenditure. Persons aged 25 years and older demonstrated an inverse relationship between physical activity and symptoms of depression.

Although many cross-sectional studies suggest a positive association between physical activity and mental health, they do not necessarily indicate a cause-and-effect relationship. Persons who have good mental health may simply be more likely to be active. Another possibility is that physical activity and mental health vary together, in which case a third variable, such as chronic health conditions, would mediate this relationship.

Cohort studies provide additional insights into whether physical activity contributes to the primary prevention of mental health problems (Table 4-9). In one cohort study of 1,900 U.S. adults, a cross-sectional analysis of the baseline data revealed an association between depressive symptoms and little or no involvement in physical activity (Farmer et al. 1988). At 8-year follow-up, little or no recreational physical activity was found to be a significant predictor of increased depressive symptoms among white women who had reported few depressive symptoms

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**Table 4-9. Longitudinal population-based studies of physical activity as related to depressive symptoms**

Study	Population	Definition of physical activity	Definition of cancer
Farmer et al. (1988)	NHANES I Follow-up Study participants, white adults, aged 25–77 years, 1975 baseline	Little or no exercise done for recreation at baseline	Depressive symptoms scores of (a) < 16 and (b) ≥ 16 at baseline
Camacho et al. (1991)	Alameda County, CA population study participants aged ≥ 20 years; or ever married, 1965 baseline	Self-reported frequency of involvement in active sports, swimming or walking, daily exercise, and gardening; (low = 0–4, moderate = 5–8, high = 9–14)	Depressive symptoms at 1974 follow-up
Weyerer (1992)	German population study participants aged ≥ 16 years at 1975–1979 baseline	Regular, occasional, or no exercise at baseline based on single question: How often do you currently exercise for sports?	Psychiatric interview assessed depression at follow-up (1980–1984)
Paffenbarger, Lee, Leung (1994)	Harvard alumni study participants, men aged 35–74 years, 1962 or 1966 baseline	(a) ≤ 1 hour, 1–2 hours, 3+ hours of sports play/week at baseline  (b) < 1,000 kcal, 1,000–2,499 kcal, or 2,500+ kcal/week at baseline	Physician-diagnosed depression at 1988 follow-up

## The Effects of Physical Activity on Health and Disease

Main findings	Dose response*	Adjustment for confounders and other comments
(a) Men: 1.3 (95% CI, 0.5–3.1) Women: 1.9 (95% CI, 1.1–3.2) (b) Men: 12.9 (95% CI, 1.7–98.9) Women: 2.0 (95% CI, 0.8–14.5)	NA	Odds ratio adjusted for age, education, chronic conditions, employment status, household income, physical activity apart from recreation at baseline, length of follow-up
Relative to high active, low active men: 1.76 (95% CI, 1.06–2.92) moderate active men: 1.46 (95% CI, 0.91–2.34) low active women: 1.70 (95% CI, 1.06–2.70) moderate active women: 1.00 (95% CI, 0.63–1.59)	Yes  No  NA  NA	Odds ratio adjusted for age, income, race, smoking status, alcohol consumption, relative weight for height, education, chronic conditions, physical symptoms/disability, stress events, isolation, feelings of anomie
Relative to regular exercise, men/no exercise: 1.15 (95% CI, 0.30–4.36) men/occasional exercise: 0.27 (95% CI, 0.03–2.35) women/no exercise: 0.70 (95% CI, 0.30–1.62) women/occasional exercise: 0.65 (95% CI, 0.26–1.61) Total/no exercise: 0.88 (95% CI, 0.44–1.77) Total/occasional exercise: 0.70 (95% CI, 0.30–1.50)	NA  No  NA  No  NA  No	Odds ratio adjusted for age, social class, and physical health
Relative to ≤ 1 hour of sports play/week, RR for 1–2 hours = 0.96, RR for 3+ hours = 0.73	Yes	Adjusted for age
Relative to < 1,000 kcal/week, RR for 1,000–2,499 kcal/week = 0.83 RR for 2,500 kcal/week = 0.72	Yes	

Abbreviations: CI = confidence interval; NA = not available; NHANES = National Health and Nutrition Examination Survey; RR = relative risk.

\*A dose-response relationship requires more than 2 levels of comparison. In this column, "NA" means that there were only 2 levels of comparison; "No" means that there were more than 2 levels but no dose-response gradient was found; "Yes" means that there were more than 2 levels and a dose-response gradient was found.

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at baseline. Among white men who had excessive depressive symptoms at baseline, low levels of recreational activity predicted continued depressive symptoms at follow-up.

A cross-sectional analysis (Camacho et al. 1991) of 1965 baseline data on 6,928 U.S. residents revealed an inverse association between physical activity (low, moderate, and high levels of participation in active sports, swimming or walking, doing exercises, or gardening) and depressive symptoms. Follow-up study of the men and women who had few depressive symptoms in 1965 showed that those who had low levels of physical activity were at greater risk than their highly active counterparts for having a high number of depressive symptoms in 1974.

A 23- through 27-year follow-up study of 10,201 Harvard alumni men revealed that level of physical activity reported at an initial interview in 1962 or 1966 was inversely related to self-reported physician-diagnosed depression in 1988 (Paffenbarger, Lee, Leung 1994). Physical activity in 1962 and 1966 was defined as the number of hours per week spent doing physical activities (e.g., golf, gardening, carpentry, tennis, swimming, brisk walking, jogging, or running); from this information, a physical activity index was computed as kilocalories of energy expended per week. In 1988, respondents were asked whether they had ever been told by a physician that they had health problems (e.g., CHD, emphysema), including depression, and to list the year of onset. Incidence of depression was determined by an attack first experienced (at a known age of the respondent) during the follow-up period. This study was unique in that the relationship between physical activity and deaths due to suicides was also evaluated. The incidence of suicide (as identified on death certificates) was largely unrelated to the 1962 or 1966 physical activity history of the college alumni. However, the relative risk of depression was 27 percent lower for men who had reported playing 3 or more hours of sports each week than for men who had reported playing none. In addition, men who had expended 1,000 to 2,499 kilocalories per week and those who had expended 2,500 kilocalories or more per week were at 17 percent and 28 percent less risk for depression, respectively, than men who had expended fewer than 1,000 kilocalories per week.

In a study of rural Europeans ( $n = 1,536$ ), a cross-sectional association was observed between inactivity (no physical exercise or sports participation) and depression (diagnosed by research psychiatrists) (Weyerer 1992). However, low levels of physical activity at baseline were not a risk factor for depression at 5-year follow-up for men or women in this study.

Two of the epidemiologic studies reviewed above examined a possible dose-response relationship. In one study (Camacho et al. 1991), the baseline prevalence of symptoms of depression was higher for persons reporting low levels of physical activity than for highly active persons; the risk was intermediate for the moderately active group. At follow-up, the incidence of depressive symptoms revealed a significant difference only between persons in the lowest and highest activity groups. In the second study (Paffenbarger, Lee, Leung 1994), an inverse dose-response gradient was found between the baseline self-reported amount of physical activity calculated as kilocalories per week ( $< 1,000$ ,  $1,000-2,499$ ,  $\geq 2,500$ ) and the follow-up incidence of physician-diagnosed depression. Men who at baseline had reported no hours of sports play per week had a similar follow-up incidence of depression as men who reported 1 to 2 hours of weekly play; but men who had participated in 3 or more hours of weekly play had a 27 percent lower risk for developing depression than the least active group.

The findings from these two studies provide limited support for a dose-response relationship between levels of physical activity and measures of depressive symptoms or depression. However, among some endurance athletes, mood disturbances (decreased vigor and increased fatigue, anxiety, and symptoms of depression) have been observed with overtraining; mood improved after training was tapered (Morgan et al. 1987). It is therefore conceivable that for the general population, too strenuous a physical activity regimen may lead to deleterious effects on mental health (Morgan 1979b, 1994; Polivy 1994; Raglin 1990). To date, research has not identified a threshold or an optimal frequency, duration, or intensity of physical activity necessary to improve mental health status.

### Biologic Plausibility

Some researchers have proposed that exercise-induced changes in brain neuroreceptor concentrations of monoamines (norepinephrine, dopamine, or serotonin) (Ransford 1982) or endogenous opiates (endorphins and enkephalins) (Moore 1982) may help to favorably alter mood. The increased core body temperature that occurs from physical activity may also decrease muscle tension (DeVries 1981). Other hypothalamic, metabolic, hormonal, or cardiorespiratory changes that result from training may eventually be linked to enhanced mental health.

Psychosocial aspects of physical activity, such as having the opportunity for social interaction and support (Hughes, Casal, Leon 1986), experiencing increased feelings of self-mastery and self-efficacy (Simons et al. 1985; Hughes, Casal, Leon 1986), and experiencing relief from daily stressors (Bahrke and Morgan 1978), may improve mental health status in some people.

### Conclusions

The literature reported here supports a beneficial effect of physical activity on relieving symptoms of depression and anxiety and on improving mood. There is some evidence that physical activity may protect against the development of depression, although further research is needed to confirm these findings.

### Health-Related Quality of Life

For several decades, it has been recognized that health should not be defined simply as the absence of disease and disability; rather, health is now conceptualized by the World Health Organization as a positive state of physical, mental, and social well-being (World Health Organization 1947). This recognition has resulted in an increasing clinical, scientific, and public interest in the assessment and promotion of health-related quality of life (HRQL).

Kaplan and Bush (1982) introduced the term HRQL to capture the influence that health status and health care have on the quality of day-to-day life. Viewed as a multidimensional construct that represents a person's overall satisfaction with life, HRQL includes the following dimensions: cognitive, social, physical, and emotional functioning; personal

productivity; and intimacy (Shumaker, Anderson, Czajkowski 1990). Rejeski, Brawley, and Shumaker (1996) have shown that physical activity has significant potential to influence HRQL. The most direct effects are likely in the areas of psychological well-being (e.g., self-concept, self-esteem, mood, and affect), perceived physical function (e.g., perceived ability to perform activities of daily living), physical well-being (e.g., perceived symptoms and perceived physical states, such as dyspnea, pain, fatigue, and energy), and, to a limited extent, cognitive function.

In a recent review, McAuley (1994) concluded that a positive association exists between physical activity habits and self-esteem in both young adults and children. The strength of this relationship increases when physical activity is personally valued and when measures of psychological well-being are specific rather than general. Among nonclinical and clinical samples of men and women, this association is observed both with the long-term effects of exercise training and with the immediate, short-term effects of a single episode of activity.

In a review of studies of middle-aged participants (mean age, 56.7 years), McAuley and Rudolph (1995) found correlations between involvement in physical activity and psychological well-being that were similar to those patterns observed among younger persons. Further, the strength of these relationships was directly related to the length of time that the participants had been involved in physical activity programs. This moderating effect requires cautious interpretation because of the possibility of selective adherence. There was little evidence that the relationship between physical activity and psychological well-being was affected by either sex or age. Finally, although a number of studies noted improvements in both the cardiorespiratory fitness and the psychological well-being of older adults, these improvements were not necessarily correlated (McAuley and Rudolph 1995). Involvement in physical activity may thus increase the psychological well-being of older adults independently of cardiorespiratory fitness (Brown and Wang 1992; King, Taylor, Haskell 1989; Landers and Petruzzello 1994; Martinsen and Stephens 1994; McAuley and Rudolph 1995).

Other data suggest that physical activity is related to perceived improvement in physical function in activities of daily living. However, there is a limit



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to this effect, since sedentary people can usually do their daily tasks. Most research on this aspect of HRQL is thus confined to populations of people who, because of health problems, have restrictions in their activities of daily living. The growing body of literature on this topic indicates that patients whose physical function is compromised by heart disease (Ewart 1989) or arthritis (Fisher et al. 1993) experience improved daily function from increases in physical activity.

HRQL requires a number of different types of measurements; however, few studies on physical activity have used a multidimensional measurement scheme. Exceptions include a randomized clinical trial involving healthy elderly persons (Stewart, King, Haskell 1993) and a 2-year observational study of persons with chronic disease (Stewart et al. 1994). In the clinical trial, healthy persons who were assigned to endurance exercise had better self-reported ratings of their physical functioning and health (e.g., physical and role function, experiencing of pain, perception of health status) than control participants, yet endurance training brought no changes in self-reported energy/fatigue, psychological distress, or psychological well-being. By contrast, among persons with chronic diseases, physical activity was associated with improvement in both psychological well-being and physical function; however, the magnitude of these effects was highly dependent on the status of the patient's chronic disease. Participants who have lower levels of mental or physical health may have the most to gain from physical activity (Lennox, Bedell, Stone 1990; Morgan et al. 1970; Simons and Birkimer 1988; Rejeski et al. 1995), since they have more room to improve their health status than people already possessing good health.

A relatively small number of cross-sectional studies have shown a strong positive association between regular physical activity and cognitive and neuropsychological performance on tasks such as math, acuity, and reaction time (Dustman, Emmerson, Shearer 1994; Thomas et al. 1994). However, longer-term training studies (2 or more years) are required to confirm whether aerobic exercise has a pronounced effect on cognitive function. Also unclear are whether the effects of low-intensity physical activity are similar to those of

aerobic exercise and whether objective measures of cognitive function can elucidate the perceived cognitive function of participants (Dustman, Emmerson, Shearer 1994).

## Conclusions

Physical activity appears to improve psychological well-being. Among people compromised by ill health, physical activity appears to improve their ability to perform activities of daily living.

## Adverse Effects of Physical Activity

Although physical activity has numerous health benefits, its potential adverse effects must also be considered. Listing the potential risks associated with physical activity is a straightforward matter. It is much more difficult to determine how commonly they occur among people who are physically active.

## Types of Adverse Effects

### *Musculoskeletal Injuries*

Acute stress from sudden forceful movement can cause strains, tears, and even fractures. For example, a vigorous swing of a baseball bat can lead to a dislocated shoulder. An attempt to accelerate forward in tennis can tear an Achilles tendon. Bending to retrieve an object can rupture an intervertebral disc. Injuries like these can result from any activity, exercise, or sport that features sudden movements, such as those that can occur in professional or amateur track and field, racquet sports, basketball, baseball, football, soccer, and golf. Collisions with equipment, other participants, and surfaces can also produce severe injury. Children and adolescents with developing bodies are at special risk of permanent physical damage if injury occurs to the growth plates of long bones or to other bone or connective tissue structures.

Activities that involve repetitive motions, sometimes with traumatic contact with a ground surface or ball, are associated with other musculoskeletal injuries. An extensive literature describes injuries related to jogging and running (Hoeberigs 1992; Rolf 1995; Van Mechelen 1992). Lower-extremity injuries appear to be the most common; of these,

the knee, ankle, and foot have the highest proportions of injuries (e.g., torn cartilage, tendinitis, plantar fasciitis, neuromas, and shinsplints). Injuries are also seen in excessive bicycling (e.g., ulnar nerve palsies, ischial bursitis [Cohen 1993; Mellion 1991; Pfeiffer and Kronisch 1995]), swimming (e.g., shoulder pain [Allegrucci, Whitney, Irrgang 1994; Johnson, Sim, Scott 1987]), racquet sports (e.g., epicondylitis [Kamien 1990]), aerobic dancing (e.g., shin pain and plantar fasciitis [Richie, Kelso, Bellucci 1985]), and rowing (e.g., back and knee injuries [Howell 1984]).

### **Metabolic Abnormalities**

Severe exertion, particularly of prolonged duration and under hot or humid conditions, can lead to hyperthermia, electrolyte imbalance, and dehydration (England et al. 1982; Frizzell et al. 1986; Surgenor and Uphold 1994). Timely fluid intake and replacement, with proper electrolyte and caloric composition, can prevent or ameliorate such metabolic upsets. Hypothermia is a risk in many water sports and for any activities undertaken in cold weather (or even cool weather if inadequate clothing is worn). Extreme endurance training regimens can lead to endocrine system alterations, sometimes resulting in anovulation and amenorrhea in females, in association with a decrease in body weight below a critical lean mass, as well as with a decrease in bone mass (Shangold 1984). Hypoglycemia can occur in people with diabetes if they do not develop a routine of regular activity in conjunction with regular monitoring of their blood sugar (and adjustment of their medication accordingly).

### **Hematologic and Body Organ Abnormalities**

Anemia is reported in athletes vigorously engaged in sports such as long-distance running; hemoglobinuria can occur secondary to breakage of red blood cells during the repetitive impact of distance running, and hematuria can occur when distance running traumatizes the bladder or other structures in the genitourinary system. Rhabdomyolysis, the leakage of contents of muscle cells, can occur as a result of strenuous activity, such as weight lifting or military basic training, and can lead to renal failure (Kuipers 1994; Sinert et al. 1994).

### **Hazards**

Cyclists, runners, and walkers often face risks associated with travel on roadways—collisions with motor vehicles, injuries from falls secondary to uneven surfaces, and attacks by animals or humans. Skiers and skaters must contend with falls at high velocities. Baseball players may be struck by a thrown or batted ball or injured by a spike-soled shoe. Basketball and soccer entail collisions with other players and frequent falls to hard surfaces. Football, hockey, and boxing, by their very nature, are sports where sanctioned and moderately controlled interpersonal violence often leads to contusions, lacerations, musculoskeletal injury, and fractures, as well as to concussions and chronic disability (Kraus and Conroy 1984).

### **Infectious, Allergic, and Inflammatory Conditions**

Swimming increases the risk of otitis externa ("swimmer's ear"). Overtrained athletes may have an increased risk of infections from immunosuppression (Newsholme and Parry-Billings 1994). Exertion may provoke asthmatic attacks, usually occurring after exercise in susceptible individuals (Anderson, Daviskas, Smith 1989).

### **Cardiac Events**

As was discussed earlier in this chapter, regular physical activity improves cardiorespiratory fitness and reduces the risk of CVD mortality over the long term, although it can acutely increase risk for untoward cardiac events in the short term. Persons with compromised coronary circulation may develop angina or acute myocardial infarction during vigorous activity (Mittleman et al. 1993; Willich et al. 1993). Arrhythmias may be precipitated by a combination of exertion and underlying heart disease, and some can lead to sudden death (Kohl et al. 1992; Koplan 1979; Siscovick et al. 1984; Thompson, Funk, et al. 1982). Compared with sedentary people who suddenly begin exercising vigorously, persons who exercise regularly have a lower risk of exercise-related sudden death, although even this group has a transient elevation of risk during and immediately after vigorous exercise (Kohl et al. 1992; Siscovick et al. 1984). Nonetheless, the net effect of regular physical activity is to decrease the risk of cardiac death.

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### Occurrence of Adverse Effects

Determining the incidence or prevalence of adverse effects of physical activity, or factors that influence the likelihood of their occurrence, is hampered by not knowing how many people have similar physical activity patterns and are thus similarly at risk of an adverse event, or how many inactive people sustain similar injuries. Nevertheless, a few studies have provided some insight into the occurrence of adverse events. Of the activities that are common in the United States, including jogging/running, walking, gardening, bicycling, swimming, aerobic dance, and softball, running has received the most attention by researchers.

Injuries among runners are common, ranging from 25 through 65 percent (Jones, Cowan, Knapik 1994). Most running-related injuries involve the leg and foot and are usually self-correcting in a relatively short time. Studies of such injuries have generally shown that occurrence of musculoskeletal injury is directly related to mileage run (Blair, Kohl, Goodyear 1987; Hoeborgs 1992; Koplan et al. 1982; Macera 1992; Macera et al. 1989; Marti 1988; Marti et al. 1988; Walter et al. 1989) or to frequency or duration of running (Pollock et al. 1977). Previous injury appears to be a risk factor for subsequent injury. In one small study of people aged 70–79 years, the injury rate was lower for walking than jogging (5 percent vs. 57 percent) (Pollock et al. 1991). Whether this finding is true only among the elderly or is characteristic of these activities at all ages remains to be determined.

Although few studies of aerobic dance have been conducted, the injury rate appears to be higher among those taking more than 4 classes per week (Richie, Kelso, Bellucci 1985).

### Conclusions

A wide spectrum of adverse events can occur with physical activity, ranging from those that cause minor inconvenience to those that are life-threatening. At least some of the musculoskeletal injuries are likely to be preventable if people gradually work up to a physical activity goal and avoid excessive amounts of physical activity or excessively high levels of intensity. Although adverse cardiac events are more likely to occur with physical exertion, the net effect

of regular physical activity is a lower CVD mortality rate among active than inactive people (see earlier sections of this chapter).

People should be advised not to undertake physical activities well beyond their normal level of exertion. Inactive people wishing to begin a new program of moderate activity should begin with short durations and gradually lengthen them toward their target. Men over age 40 and women over age 50 who wish to begin a new program involving vigorous-intensity activity, people who have preexisting health problems, and people who are at high risk of CVD should consult a physician before embarking on a program of physical activity to which they are unaccustomed (ACSM 1991).

## Nature of the Activity/Health Relationship

### Causality

The studies reviewed in this chapter indicate that physical activity is associated with a reduction in risk of all-cause mortality, all CVDs combined, CHD, hypertension, colon cancer, and NIDDM. To evaluate whether the information presented is sufficient to infer that these associations are causal in nature, it is useful to review the evidence according to Hill's classic criteria for causality (Hill 1965; Paffenbarger 1988).

*Strength of Association.* The numerous estimated measures of association for cardiovascular outcomes presented in this chapter generally fall within the range of a 1.5- to 2.0-fold increase in risk of adverse health outcomes associated with inactivity. This range represents a moderately strong association, similar in magnitude to the relationship between CHD and smoking, hypertension, or elevated cholesterol. The associations with NIDDM, hypertension, and colon cancer have been somewhat smaller in magnitude. The difficulty in measuring physical activity may lead to substantial misclassification, which in turn would bias studies toward finding less of an effect of activity than may actually exist. On the other hand, not controlling for all potential confounders could bias studies toward finding more of an effect than may actually exist. Efforts to stratify studies of physical activity and CHD by the quality of

measurement have found that the methodologically better studies showed larger associations than those with lower quality scores (Powell et al. 1987; Berlin and Colditz 1990). In addition, cardiorespiratory fitness, which is more objectively and precisely measured than the reported level of physical activity, often is also more strongly related to CVD and mortality. Measures of association between physical activity and health outcomes thus might be stronger if physical activity measurements were more accurate.

*Consistency of Findings.* Although the epidemiologic studies of physical activity have varied greatly in methodology, in ways of classifying physical activity, and in populations studied, the findings have been remarkably consistent in supporting a reduction in risk as a function of greater amounts of physical activity, or conversely, an increase in risk as a function of inactivity.

*Temporality.* For most of the health conditions included in this chapter (all-cause mortality, CVD, CHD, hypertension, NIDDM), longitudinal data from cohort studies have been available and have confirmed a temporal sequence in which physical activity patterns are determined prior to development of disease. For obesity and mental health, fewer longitudinal studies have been conducted, and findings have been more equivocal. Perhaps the strongest evidence for temporality comes from two studies of the effect of changes in activity or fitness level. Men who became more active or more fit had a lower mortality rate during follow-up than men who remained inactive or unfit (Paffenbarger et al. 1993; Blair et al. 1995).

*Biological Gradient.* Studies of all-cause mortality, CVD, CHD, and NIDDM have shown a gradient of greater benefit associated with higher amounts of physical activity. Most studies that included more than two categories of amount of physical activity and were therefore able to evaluate a dose-response relationship found a gradient of decreasing risk of disease with increasing amounts of physical activity (see Tables 4-1 through 4-8).

*Biologic Plausibility.* Evidence that physiologic effects of physical activity have beneficial consequences for CHD, NIDDM, and obesity is abundant (see Chapter 3, as well as the biologic plausibility sections of this chapter). Such evidence includes beneficial effects on physiologic risk factors for

disease, such as high blood pressure and blood lipoproteins, as well as beneficial effects on circulatory system functioning, blood-clotting mechanisms, insulin production and glucose handling, and caloric balance.

*Experimental Evidence.* Controlled clinical trials have not been conducted for the outcomes of mortality, CVD, cancer, obesity, or NIDDM. However, randomized clinical trials have determined that physical activity improves these diseases' risk factors, such as blood pressure, lipoprotein profile, insulin sensitivity, and body fat.

The information reviewed in this chapter shows that the inverse association between physical activity and several diseases is moderate in magnitude, consistent across studies that differed substantially in methods and populations, and biologically plausible. A dose-response gradient has been observed in most studies that examined more than two levels of activity. For most of the diseases found to be inversely related to physical activity, the temporal sequence of exposure preceding disease has been demonstrated. Although controlled clinical trials have not been conducted (and are not likely to be conducted) for morbidity and mortality related to the diseases of interest, controlled trials have shown that activity can improve physiologic risk factors for these diseases. From this large body of consistent information, it is reasonable to conclude that physical activity is causally related to the health outcomes reported here.

### Population Burden of Sedentary Living

Given that the relationship between activity and several diseases is likely to be causal, it follows that a large number of Americans unnecessarily become ill or die each year because of an inactive way of life. Published estimates of the number of lives lost in a year because of inactivity have ranged from 200,000 for inactivity alone to 300,000 for inactivity and poor diet combined (Hahn et al. 1990; Powell and Blair 1994; McGinnis and Foege 1993). Such estimates are generally derived by calculating the population attributable risk (PAR), which is based on both the relative mortality rate associated with inactivity and the prevalence of inactivity in the population. Such estimates are inherently uncertain because they do

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not take into account the reality that some people have more than one risk factor for a disease; for these people, the elimination of a single risk factor (e.g., by becoming physically active) may not reduce mortality risk to the level attainable for people who initially have only that one risk factor. PAR methods thus overestimate the proportion of deaths avoidable by eliminating one modifiable risk factor, in this case physical inactivity. On the other hand, PAR estimates of avoidable mortality do not address other important aspects of the population burden of sedentary living. The benefits of reducing the occurrence of CHD, colon cancer, and diabetes greatly surpass the benefits of reducing premature mortality, yet the reductions in avoidable disease, disability, suffering, and health care costs have not been calculated. Similarly, the health benefits of improved mood, quality of life, and functional capacity have not been quantified. Although the total population burden of physical inactivity in the United States has not been quantified, sedentary living habits clearly constitute a major public health problem.

### Dose

Using the epidemiologic literature to derive recommendations for how much and what kind of physical activity a person should obtain is problematic, in part because the methods for measuring and classifying physical activity in epidemiologic studies are not standardized. Measurement of physical activity generally relies on self-reported information in response to questionnaires, although some studies use occupation to categorize a person's presumed level of physical activity at work. Responses to questions or occupational activity categories are usually transformed, using a variety of methods, into estimates of calories expended per week, minutes of activity per week, categories of total activity, or other types of composite scores.

Numerous studies have used this type of information to estimate total amount of activity, and many have been able to explore dose-response relationships across categories of activity amount. For the most part, these studies demonstrate that amount of benefit is directly related to amount of physical activity (see Tables 4-1 through 4-8), rather than showing a threshold level of activity necessary before health benefits accrue. Such studies are less helpful,

however, in assessing the relationship of health benefits to intensity of physical activity (i.e., how hard one must work during the activity itself) because few studies have separately measured or analyzed levels of intensity while taking into account the other dimensions of activity (e.g., frequency, duration, total caloric expenditure). As described earlier, however, for some health benefits (e.g., blood pressure lowering), clinical trials of exercise intensity suggest similar, if not greater, benefit from moderate- as from vigorous-intensity exercise.

It is often asked how little physical activity a person can obtain and still derive health benefit. Although the dose-response relationship appears not to have a lower threshold, thereby indicating that any activity is better than none, some quantitation of a target "dose" of activity is helpful for many people. It has been shown that total amount of physical activity (a combination of intensity, frequency, and duration) is related to health outcomes in a dose-response fashion, but the absolute difference in amount of physical activity in kilocalories of energy expended between exposure categories has not been estimated routinely. Several studies, however, have estimated average caloric expenditure for the activity categories studied and thus allow quantitation of amount of physical activity associated with improved health outcomes. Paffenbarger and colleagues (1986) found that compared with the least active group in the study, those who expended 71–143 kilocalories of energy per day had a 22 percent reduction in overall mortality, and those who expended 143–214 kilocalories per day had a 27 percent reduction. Leon and colleagues (1987) showed that a difference of about 30 minutes per day of activity (light, moderate, and vigorous activity combined), equivalent to an average difference of about 150 kilocalories of energy expended per day, was associated with a 36 percent lower risk of CHD mortality and a 27 percent lower risk of all-cause death, after the analysis adjusted for other factors that can effect CHD and total mortality. Slaterry and colleagues (1989) found that a daily average of 73 more kilocalories of total activity than were expended among the least active group was associated with a 16 percent reduction in CHD mortality and a 14 percent reduction in all-cause mortality. Furthermore, in the majority (62 percent)

of that study population, no vigorous activity was reported. In that group, a daily average of 150 kilocalories greater expenditure in light-to-moderate activity was associated with a 27 percent lower CHD mortality and a 19 percent lower total mortality. The effects of light-to-moderate activity on CHD death remained significant after the analysis adjusted for potential confounders. Similarly, in a study of NIDDM (Helmrich et al. 1991) that showed a significant inverse trend between kilocalories expended in activity and development of NIDDM, total activity of 140–215 kilocalories per day was associated with a 21 percent reduction in NIDDM onset. In the group that obtained this level of energy expenditure without any vigorous sports participation, the reduction in NIDDM onset was 13 percent.

Based on these studies, it is reasonable to conclude that activity leading to an increase in daily expenditure of approximately 150 kilocalories/day (equivalent to about 1,000 kilocalories/week) is associated with substantial health benefits and that the activity does not need to be vigorous to achieve benefit. It should be emphasized that this is an estimate based on few studies, and that further research will be required to refine it. For example, it is not clear whether it is the total amount of caloric expenditure or the amount of caloric expenditure per unit of body weight that is important. Nonetheless, this amount of physical activity can be obtained in a variety of ways and can vary from day to day to meet the needs and interests of the individual. An average expenditure of 150 kilocalories/day (or 1,000 kilocalories/week) could be achieved by walking briskly for 30 minutes per day, or by a shorter duration of more vigorous activity (e.g., 15 minutes of running at 10 minutes per mile), or by a longer duration of more vigorous activity less frequently (e.g., running at 10 minutes per mile for about 35 minutes 3 times per week). Other sample activities are provided in Table 4-10.

In addition to the health effects associated with a moderate amount of physical activity, the dose-response relationships show that further increases in activity confer additional health benefits. Thus people who are already meeting the moderate activity recommendation can expect to derive additional benefit by increasing their activity. Since amount of activity

is a function of intensity, frequency, and duration, increasing the amount of activity can be accomplished by increasing any, or all, of those dimensions.

There is evidence that increasing physical activity, even after years of inactivity, improves health. Studies of the health effects of increasing physical activity or fitness (Paffenbarger et al. 1993; Blair et al. 1995) have shown a reduced mortality rate in men who become more active or more fit compared with those who remain sedentary. This benefit was apparent even for men who became physically active after the age of 60.

Most importantly, a regular pattern of physical activity must be maintained to sustain the physiologic changes that are assumed responsible for the health benefits (see Chapter 3). Thus it is crucial for each person to select physical activities that are sustainable over the course of his or her life. For some people, a vigorous workout at a health club is the most sustainable choice; for others, activities integrated into daily life (e.g., walking to work, gardening and household chores, walking after dinner) may be a more sustainable option. Periodic reevaluation may be necessary to meet changing needs across the life span.

A related issue of pattern of physical activity (frequency and duration in the course of a day) has recently come under review. Three studies have held constant both total amount of activity and intensity of activity while daily pattern was varied (one long session versus shorter, more frequent sessions). Two studies showed equivalent increases in cardiorespiratory fitness (Jakicic et al. 1995; Ebisu 1985). One study showed gains in cardiorespiratory fitness for both the “short bout” and “long bout” groups, although on one of three measures (maximal oxygen uptake versus treadmill test duration and heart rate at submaximal exercise), the gain in fitness was significantly greater in the long bout group (DeBusk et al. 1990). These observations give rise to the notion that intermittent episodes of activity accumulated in the course of a day may have cardiorespiratory fitness benefits comparable to one longer continuous episode. Whether this assumption holds true for the outcomes of disease occurrence and death remains to be determined. Nevertheless, some previous observational studies have shown lower rates of CHD, CVD, and all-cause mortality among people with an active

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**Table 4-10. Duration of various activities to expend 150 kilocalories for an average 70 kg adult**

Intensity	Activity	Metabolic equivalents METs*	Approximate duration in minutes†
Moderate	Volleyball, noncompetitive	3.0	43
Moderate	Walking, moderate pace (3 mph, 20 min/mile)	3.5	37
Moderate	Walking, brisk pace (4 mph, 15 min/mile)	4.0	32
Moderate	Table tennis	4.0	32
Moderate	Raking leaves	4.5	32
Moderate	Social dancing	4.5	29
Moderate	Lawn mowing (powered push mower)	4.5	29
Hard	Jogging (5 mph, 12 min/mile)	7.0	18
Hard	Field hockey	8.0	16
Very hard	Running (6 mph, 10 min/mile)	10.0	13

\*Based on average METs in Ainsworth et al. 1993.

†Formula:  $\frac{150 \text{ kcal} \times 60 \text{ min/hour}}{\text{METs (kcal/kg/hr)} \times \text{kg}} = \text{minutes}$

lifestyle that included activities such as walking, stair climbing, household or yard work, and gardening—activities that are often performed intermittently (Leon et al. 1987; Paffenbarger et al. 1986). This information, together with evidence that some people may adhere better to an exercise recommendation that allows for accumulating short episodes of activity as an alternative to one longer episode per day (Jakicic et al. 1995), supports the notion that accumulation of physical activity throughout the day is a reasonable alternative to setting aside an uninterrupted period of time for physical activity each day. Although more research is clearly needed to better define the differential effects of various patterns of activity, experts have agreed that intermittent episodes of activity are more beneficial than remaining sedentary. This consensus is reflected in recent physical activity recommendations from the CDC and the ACSM (Pate et al. 1995) and from the NIH Consensus Development Panel on Physical Activity and Cardiovascular Disease (see Chapter 2, Appendix B).

## Conclusions

The findings reviewed in this chapter form the basis for concluding that moderate amounts of activity can protect against several diseases. A greater degree of protection can be achieved by increasing the amount of activity, which can be accomplished by increasing intensity, frequency, or duration. Nonetheless, modest increases in physical activity are likely to be more achievable and sustainable for sedentary people than are more drastic changes, and it is sedentary people who are at greatest risk for poor health related to inactivity. Thus the public health emphasis should be on encouraging those who are inactive to become moderately active. These conclusions are consistent with the recent CDC-ACSM recommendations for physical activity (Pate et al. 1995) and the NIH Consensus Development Conference Statement on Physical Activity and Cardiovascular Health (see Chapter 2, Appendix B), which emphasize the importance of obtaining physical activity of at least moderate amount on a regular basis. The recommendations also encourage those

who are already moderately active to become more active to achieve additional health benefits, by increasing the intensity, duration, or frequency of physical activity. Further study is needed to determine which combinations of these interrelated factors are most important for specific health benefits. Most important, however, is the recognition that physical activity recommendations should be tailored to an individual's needs and preferences. Encouraging sedentary people to become moderately active is likely to reduce the burden of unnecessary suffering and death only if the activity can be sustained on a daily basis for many years.

### Chapter Summary

Despite the variety of methods used to measure and classify physical activity, the imprecision of these measures, and the considerable variation in study designs and analytic sophistication, several findings consistently emerge from the epidemiologic literature on physical activity and health. Physical activity of the type that improves cardiorespiratory endurance reduces the risk of developing or dying from CVD (CHD in particular), hypertension, colon cancer, and NIDDM and improves mental health. Findings are highly suggestive that endurance-type physical activity may reduce the risk of developing obesity, osteoporosis, and depression and may improve psychological well-being and quality of life. There is promising evidence that muscle strengthening (resistance) exercise reduces the risk of falling and fractures among the elderly. Furthermore, there appears to be a dose-response relationship between physical activity and disease prevention: higher levels of activity appear to have the most benefit, but lower levels have demonstrable benefits for some diseases as well. For the U.S. population, in which the majority of people are sedentary or only minimally active, achievable increases in physical activity of a moderate amount, including some resistance exercise to strengthen muscle, are likely to substantially improve the health and quality of life of many people.

## Conclusions

### Overall Mortality

1. Higher levels of regular physical activity are associated with lower mortality rates for both older and younger adults.
2. Even those who are moderately active on a regular basis have lower mortality rates than those who are least active.

### Cardiovascular Diseases

1. Regular physical activity or cardiorespiratory fitness decreases the risk of cardiovascular disease mortality in general and of coronary heart disease (CHD) mortality in particular. Existing data are not conclusive regarding a relationship between physical activity and stroke.
2. The level of decreased risk of CHD attributable to regular physical activity is similar to that of other lifestyle factors, such as keeping free from cigarette smoking.
3. Regular physical activity prevents or delays the development of high blood pressure, and exercise reduces blood pressure in people with hypertension.

### Cancer

1. Regular physical activity is associated with a decreased risk of colon cancer.
2. There is no association between physical activity and rectal cancer. Data are too sparse to draw conclusions regarding a relationship between physical activity and endometrial, ovarian, or testicular cancers.
3. Despite numerous studies on the subject, existing data are inconsistent regarding an association between physical activity and breast or prostate cancers.

### Non-Insulin-Dependent Diabetes Mellitus

1. Regular physical activity lowers the risk of developing non-insulin-dependent diabetes mellitus.



## **Physical Activity and Health**

### ***Osteoarthritis***

1. Regular physical activity is necessary for maintaining normal muscle strength, joint structure, and joint function. In the range recommended for health, physical activity is not associated with joint damage or development of osteoarthritis and may be beneficial for many people with arthritis.
2. Competitive athletics may be associated with the development of osteoarthritis later in life, but sports-related injuries are the likely cause.

### ***Osteoporosis***

1. Weight-bearing physical activity is essential for normal skeletal development during childhood and adolescence and for achieving and maintaining peak bone mass in young adults.
2. It is unclear whether resistance- or endurance-type physical activity can reduce the accelerated rate of bone loss in postmenopausal women in the absence of estrogen replacement therapy.

### ***Falling***

1. There is promising evidence that strength training and other forms of exercise in older adults preserve the ability to maintain independent living status and reduce the risk of falling.

### ***Obesity***

1. Low levels of activity, resulting in fewer kilocalories used than consumed, contribute to the high prevalence of obesity in the United States.
2. Physical activity may favorably affect body fat distribution.

### ***Mental Health***

1. Physical activity appears to relieve symptoms of depression and anxiety and improve mood.
2. Regular physical activity may reduce the risk of developing depression, although further research is required on this topic.

### ***Health-Related Quality of Life***

1. Physical activity appears to improve health-related quality of life by enhancing psychological well-being and by improving physical functioning in persons compromised by poor health.

### ***Adverse Effects***

1. Most musculoskeletal injuries related to physical activity are believed to be preventable by gradually working up to a desired level of activity and by avoiding excessive amounts of activity.
2. Serious cardiovascular events can occur with physical exertion, but the net effect of regular physical activity is a lower risk of mortality from cardiovascular disease.

### ***Research Needs***

1. Delineate the most important features or combinations of features of physical activity (total amount, intensity, duration, frequency, pattern, or type) that confer specific health benefits.
2. Determine specific health benefits of physical activity for women, racial and ethnic minority groups, and people with disabilities.
3. Examine the protective effects of physical activity in conjunction with other lifestyle characteristics and disease prevention behaviors.
4. Examine the types of physical activity that preserve muscle strength and functional capacity in the elderly.
5. Further study the relationship between physical activity in adolescence and early adulthood and the later development of breast cancer.
6. Clarify the role of physical activity in preventing or reducing bone loss after menopause.